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The Development of a Computerized Numerical Control (CNC) Milling Machine

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Abstract
The arrangement of components on a well mapped-out printed circuit board (PCB) is important to the construction of a circuit board. A Computerized Numerical Control (CNC) drilling machine provides an advanced procedure in building of circuits, thereby relatively reducing the cost of production. In this work the design and construction of an automatic drilling machine for point to point drilling on PCB is presented. The system consists of two main parts: a mechanical setup that can move in X, Y and Z axes, and a software program that controls the overall operation of the whole system. The co-ordinates of proposed holes are to be provided in a given graphical window on the computer. The machine locates the respective co-ordinates using lead screw mechanism which is driven by A4988 stepper motor driver that is controlled by Arduino Garble (GRBL) controller using G-code. The PCB sketch which is stored as an image is converted to G-code using Inkscape graphics software. A G-code sender (GRBL controller) is then used to send the code to the machine through USB cable. The Garble (GRBL) module connects to a motor driver which drives the stepper motors. The spindle motor connects to the control board (GRBL v4) through a relay while a USB cable is used to connect the CNC controller (Engraver master) to the CNC shield (GRBL v4). Connection is established between the PC and the Garble (GBRL) board by opening USB port on the software and setting the baud rate as required. A three-axis machine was successfully constructed. The machine decodes the G-code instructions from the PC, and then monitors the motor movement which produces the required trace. The function of engraving the image on the PCB was achieved. The low cost of construction of the machine and ease of operation make it suitable for small scale manufacturers and hobbyists.

Keywords: Drilling, Milling, Engraving, G-Code, Garble, Computerized Numerical Control

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1.0 INTRODUCTION

CNC Machining is a process used in the manufacturing sector that involves the use of computers to control machine tools. Tools that can be controlled in this manner include lathes, mills, machines and grinders. The computerized numerical control (CNC) is a numerical control system where a dedicated, stored program computer is used to perform some or all of the basic numerical control functions in accordance with control programs stored in the memory of the computer.

Inspired by this CNC technology, an idea of a CNC machine that can engrave using version four Garble (GRBL) controller (Ford,2016) is hereby presented. The idea behind this project is to make a small CNC machine that can engrave on a PCB or any other improvised surfaces.

A few works have been carried out to design such machines with various types of milling features. Anderberg et al., (2012) assessed the general cost for CNC machining, and the associated energy cost are set in the context of making economic and environmental improvements. They opined that it creates an incentive for manufacturing companies to investigate the energy efficiency of manufacturing processes.Elias et al., (2013) performed the simulation and actual machining by using the LabView platform; a test run via GRBL V4 controller was done before fixing the work piece for any engraving, which prevented unnecessary damage. Xu et al., (2011) asserted that in order to make various manufacturing operations automatic and to perform it simultaneously, there is the present trend of using numerically controlled and computerized machines. The traditional approach to construct CNC machine tools has been to use rotary drive motors and ball screws to achieve table motion.

Unlike the CNC milling machine that uses five axes as described by Farouk and Li (2013) and the one that uses the LabView as reported by Elias et al. (2013), the machine described in this work uses the GRBL controller and is three-axis related.

2.0 MATERIALS AND METHOD

2.1 Block Diagram of the CNC Milling Machine

The block diagram, depicted in figure 1,shows the connection between the various modules (GRBL control board, motor drivers and the stepper motors) used to achieve the project.

The Garble (GRBL) module connects to A4988 (motor driver) which is then connected to the stepper motors. The spindle motor connects to the control board (GRBL v4)through a relay. A USB cable is used to connect the CNC controller (Engraver master) to the CNC shield (GRBL v4).

The main controller subsystem is able to interpret and communicate the limits of any job, and it can directly control the movement of the attachable tool heads. With direct connection to the main controller subsystem, the pendant subsystem is able to accept jobs uploaded through a flash drive, access information incoming through one of the active communication ports and control the direction of movement of the machine. The framework of the system is set up by the mechanical subsystem which will allow for movements in the x, y, z axes and specify limitations of any acceptable job. The main controller, pendant and mechanical subsystems are able to interact through power provided by the motor driver subsystem. The motor driver subsystem will contain a power supply that can accept input power through an electrical outlet and provide movement independently to the x, y and z axes. The schematic diagram of the electronic control circuit is shown in figure 2.

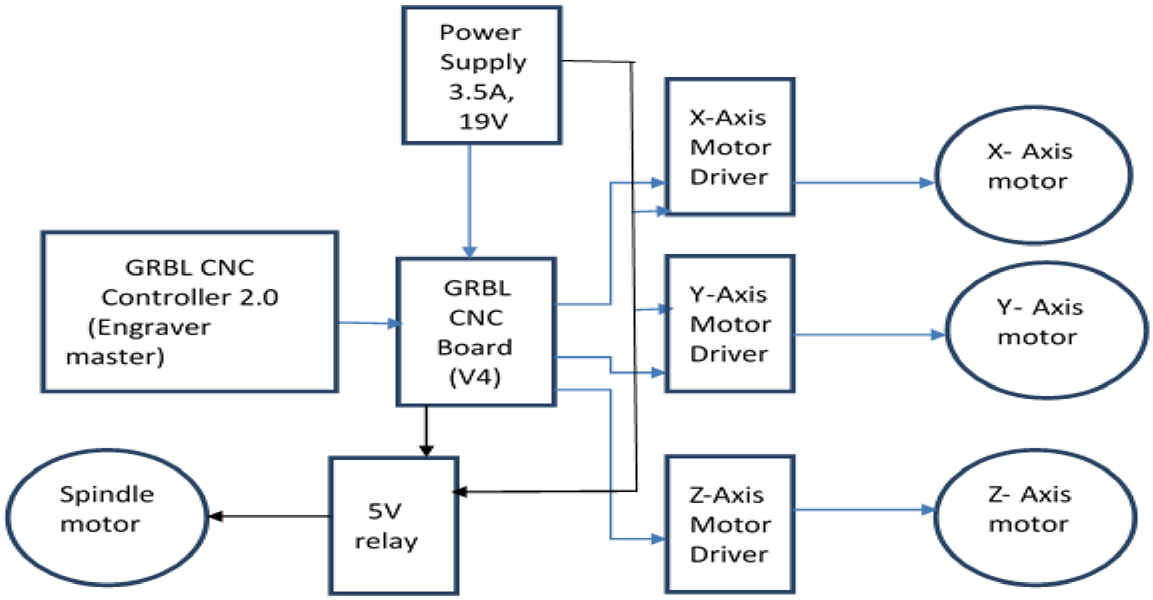

Figure 1: *Block Diagram of CNC Milling Machine.*

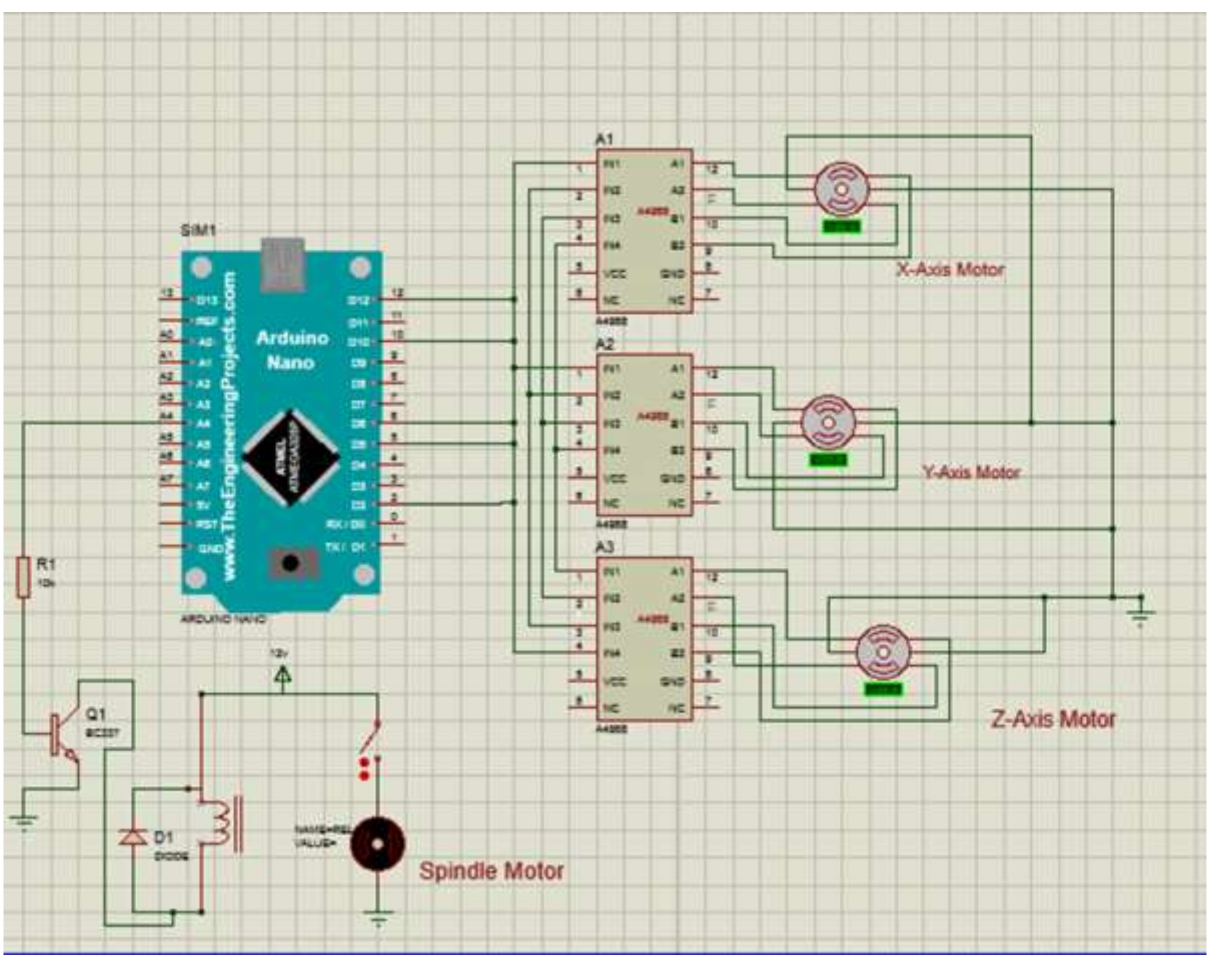

Figure 2: *Schematic Diagram of the CNC Milling Machine Control Circuit*

2.2 The Mechanical Sub-System

This part is to be designed in a 3D solid working environment using Autodesk Inventor. Due to its light weight, strength, and cost, aluminum is chosen as the primary framing metal. This includes the main chassis of the mill, which supports the X-axis, the Y-axis, the 8 x 8 work area, and the Z-axis overhead support. Chassis connections are made with bolts where possible. The long threaded rod, or all-thread, is to be made of stainless steel to allow for moderately heavy loads on the work area. To couple the stepper motors to the threaded shaft, vinyl tubing and a hose clamp is used. This will allow for some flexibility in the coupling and reduces non-tensional stresses, which can needlessly overwork the motor. Uni-polar stepper motors are to be used, but can easily be replaced with Bipolar stepper motors if need be. An AC motor is to be mounted on the Z-axis to perform the drilling operation. Ideally, a precision ¼" drill chuck will be mounted on the shaft of the AC drilling motor for easy bit changing when necessary.

2.3 SOFTWARE DESIGN

2.3.1 Programming Language

The two programming languages that have been used for the project are:

i. G-Code: G Code is a special programming language that is interpreted by Computer Numerical Control (CNC) machines to create motion and other tasks. The PCB sketch which is stored as an image is converted to G-code using Inkscape graphics software (Firangi& Megha, 2019). A G-code sender (GRBL controller) is then used to send the code to the machine through USB cable).This setup of hardware with a combination of G-code gives better accuracy and reduces the workload (Madekar *et al*., 2016)

ii. C(Computer Programming Language); the software was developed in C programming language on Arduino IDE.Computer Numerical Control (CNC) machine will be used and controlled by an innovative controlling method which converts the CNC machine language (G Code) into a form of C programming language functions (Ali, 2016).

2.3.2 The Flowchart for the Program

The G-code provides the nature of what happens on the work piece. The main program flowchart is as shown in Figure 3.The flowchart describes the machine operation. Firstly, G-code sender software (Engraver master) is launched, which initializes the stepper motors.

Connection is established between the PC and the Garble (GBRL) board through USB port. Upon receiving the G-code instructions from the PC, the machine decodes and controls the motor movement which produces the required trace.

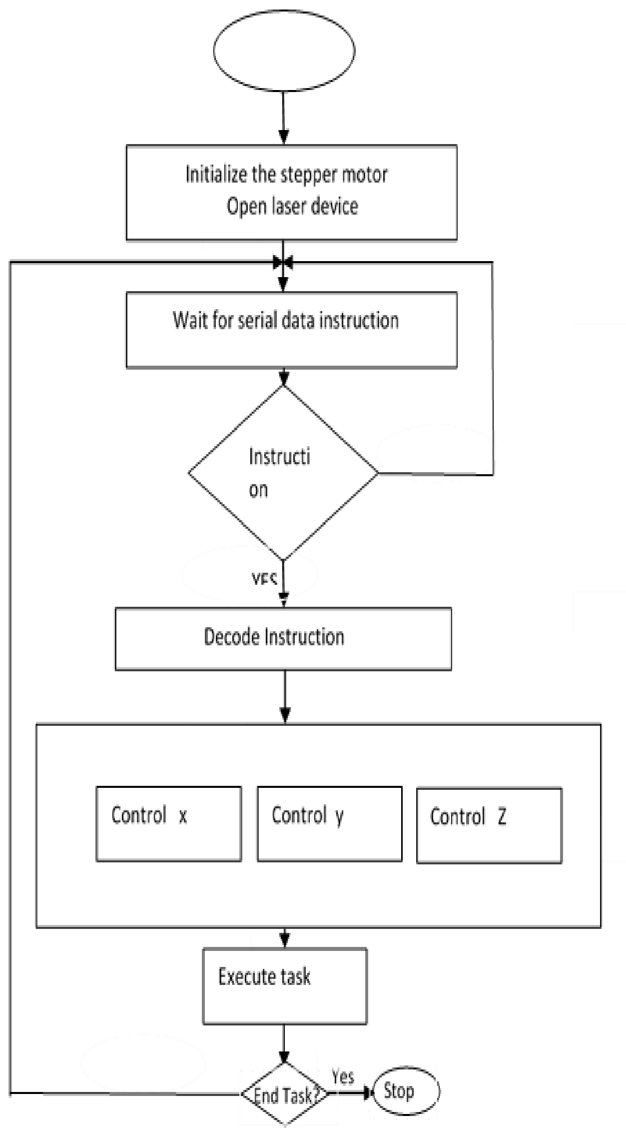

Figure 3: *Program Flowchart*

3.0 RESULTS AND DISCUSSION

The mechanical structures of the CNC milling machine that was constructed are shown in figures 4 and 5 while figure 6 shows the complete machine. Figures 7 to 9 show samples of milling on the CNC machine

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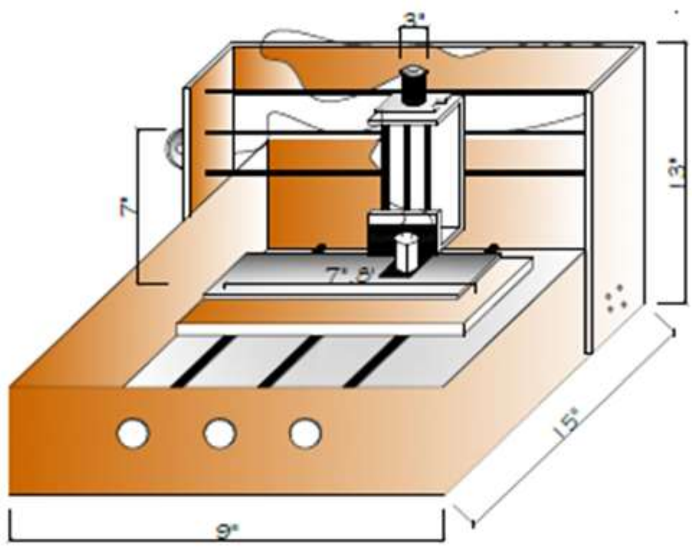

Figure 4: *Mechanical Structure of the CNC machine*

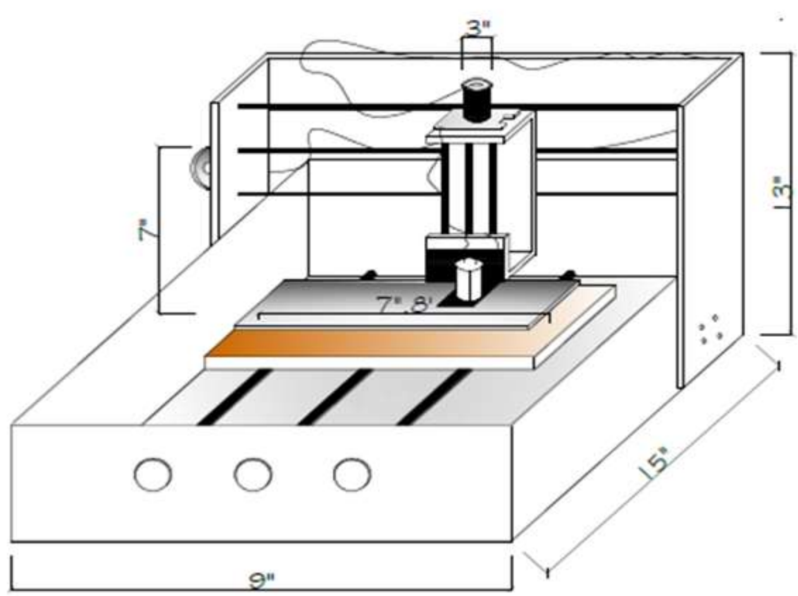

Figure 5: Further view of mechanical Structure of the CNC machine

Figure 6: View of complete CNC Milling Machine

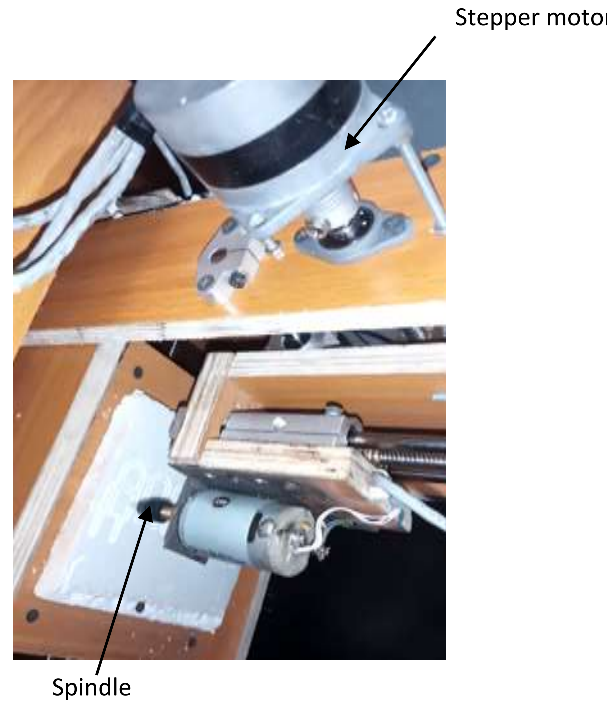

Figure 7: *Sample of milling on a white foam board*

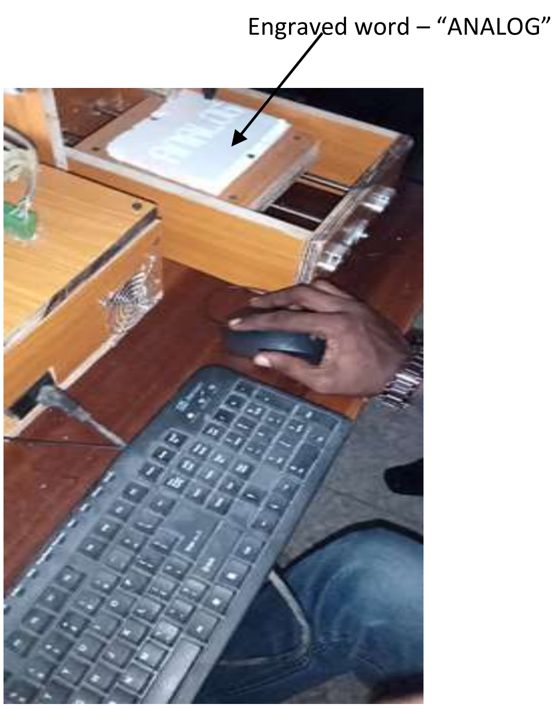

Figure 8: *Sample of milling with control setup*

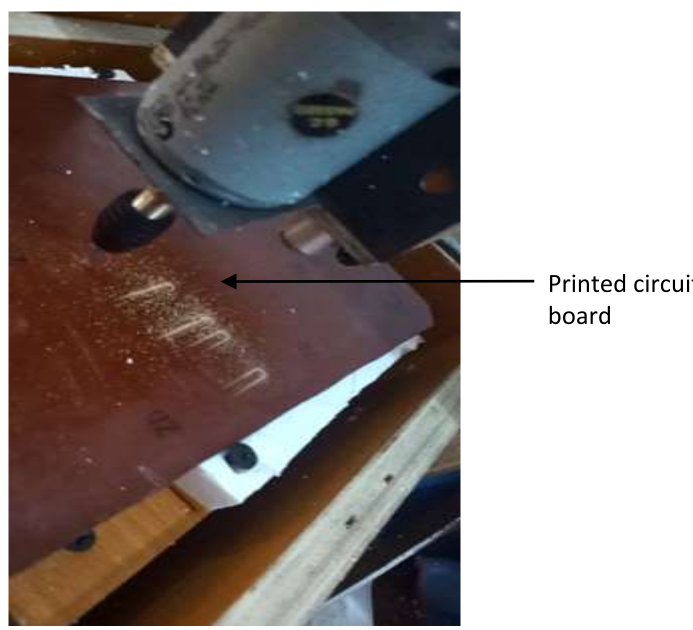

Figure 9: *Sample of Milled PCB Board*

The three-axis machine that has been designed and built is capable of making high accuracy engraving patterns on a preferred material as shown in figure 8, or on a PCB as shown in figure 9. The spindle needs to be stronger for a harder material. It is required that the corresponding G-Code be generated for the expected outcome. The bit can be changed to suit the type of operation such as milling, drilling, and cutting. In place of the spindle motor, a laser can be used for engraving purpose or a servo pen for drawing and writing. The machine is meant to be used with a work area that is not larger than 8 mm by 13 mm.

4.0 CONCLUSION

A Computerized Numerical Control (CNC) machine that is 1.5 times lower in cost compared to similar available machines in the market has been designed and built. The use of the Arduino-Garble board in conjunction with the G-code for the control of the machine, relative to the traditional use of Mach controller, makes its manufacturing to be less cumbersome.

This machine can replace many products that perform only one particularfunction and that can only accept certain types of input files. It is adaptable for use for both manufacturers and hobbyists.

By using micro stepper motors, we can improve the accuracy of the automatic milling machine and get very small deviation from our material job design. By changing our tool holder and using multipurpose tool and tool holder, we could cut, mill, lathe and grind any material. We can connect LABVIEW, MATLAB, CAD-CAM, etc. software with arduino, so we can easily operate our desired function using graphic controller and also use G-code for cutting any shape.

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